DTIC FILE COPY

(2)

AD

AD-A198 248

technical Report

United States Army
Belvoir Research, Development, & Engineering Center
Fort Belvoir, Virginia 22060-5606

Report 2465

Ported-Coax Interior Sensor (PINTS)

Authored By: **Marvin D. Robertson**

Report Date: **June 1988**

Approved for public release; distribution unlimited.

88 8

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) No. 2465	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Belvoir RD&E Center Combat Engineering Dir 6b. OFFICE SYMBOL (If applicable) STRBE-JIC	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Physical Security Equipment Division Fort Belvoir, VA 22060-5606	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Ported-Coax Interior Sensor (PINTS) (U)

12. PERSONAL AUTHOR(S)
Marvin D. Robertson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM May 87 TO Sep 87	June 1988	48

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Intrusion detection, sensor, radio frequency, guided radar, ported coax

19. ABSTRCT (Continue on reverse if necessary and identify by block number)

Although the results obtained during Concept Evaluation Program (CEP) testing of PINTS at Eglin, AFB, Florida, initially failed to achieve expected levels of false alarm rate (FAR) performance, the subsequent engineering investigation testing and data analysis positively identified the source of the high FAR problem. All test results analyzed indicated the high FAR problem could have been avoided or at least minimized by using an adequate Selection, Application, and Installation Guide (SAIG). This report presents PINTS test objectives, descriptions, results and conclusions. Also included are appendices containing reports of EG&G Energy Measurements, Inc. and the Computing Devices Company.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT [x] UNCLASSIFIED/UNLIMITED [ ] SAME AS REPORT [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Marvin D. Robertson	22b. TELEPHONE (Include Area Code) 703-664-5584 22c. Office Symbol STRBE-JIC

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

PREFACE

A Concept Evaluation Program (CEP) test of the Ported-Coax Interior Sensor (PINTS) was conducted during June 1987 at Eglin Air Force Base (AFB), Florida. Numerous false alarms (alarms due to no apparent cause when no intrusion or tampering was being attempted) were observed during the CEP test. A technical engineering investigation team was formed, whose prime objective was to determine the cause(s) of the high number of false alarms using the exact test setup used during the CEP test. The investigation team was comprised of representatives of the Belvoir Research, Development and Engineering Center's (BRDEC) Physical Security Equipment Division (PSED), EG&G Energy Measurements, Inc., and Computing Devices (COMDEV) Company.

The high false alarm rate (FAR) experienced during CEP testing at Eglin AFB was not typical of the performance demonstrated by the PINTS during any of the previous tests. The prime objective of this report is to summarize the findings and results of the investigation team and to make recommendations for enhancing sensor performance. This will be accomplished by: summarizing the factors initially believed to be possible sources of the high FAR; summarizing the investigation techniques and the results of the investigation to determine the FAR sources; giving a brief conclusion based on the results of the test and analysis; and making recommendations for enhancing sensor performance.

Although results obtained during CEP testing at the Eglin AFB test facility initially failed to achieve expected levels of false alarm rate (FAR) performance, the subsequent engineering investigation test results analysis and many hours of detailed additional testing and data analysis have positively identified the source of the high FAR problem. All test results that were analyzed indicate that the high FAR problem could have been avoided or at least minimized by the use of an adequate Selection, Application, and Installation Guide (SAIG).

CONTENTS

		Page
SECTION I	**INTRODUCTION**	**1**
	Test Purpose	1
	Test Duration and Location	2
SECTION II	**INVESTIGATION**	**5**
	General Test Description	5
	Baseline Data Testing	5
	Sensor Hardware Investigation	8
	Local Environment or Phenomena Near Facility Outside PINTS Detection Zones	10
	Local Environment or Phenomena Within Detection Zones	12
	Isolation of Ceiling from Detection Zones	16
SECTION III	**CONCLUSIONS AND RECOMMENDATIONS**	**22**
APPENDIX A	**EG & E ENERGY MEASUREMENTS, INC., REPORT DTD 17 NOV 87**	**A-1**
APPENDIX B	**COMPUTING DEVICES COMPANY, REPORT DTD 7 DEC 87**	**B-1**

TABLES

1 Analog Output Noise Comparison Chart 15

2 Data Collected for Different Cable Configurations for Large and Small Rooms 21

FIGURES

1 Sensor Electronic Unit (SEU) 3
2 Sensor Transducer Cable for PINTS 4
3 Floor Plan, Building 975, Eglin AFB 6
4 Original Cable Configuration, Building 975 7
5 RF Field for Large and Small Room 9
6 Major Functional Components of the PINTS and Interfaces 11
7 Transmit Cables Above Suspended Ceiling Receive
Cables Embedded in Concrete Floor 13
8 Controlled Environment Setup in Large Room 14
9 Small Room Cable Configuration 17
10 Floor Configuration for Small Room 19
11 Final Floor Configuration for Large Room 20

SECTION I. INTRODUCTION

TEST PURPOSE

The Ported-Coax Interior Sensor (PINTS) is a Group III Advanced Facility Intrusion Detection System (AFIDS) component. The mission essential function for the PINTS is to provide interior intrusion detection sensing. The sensor must offer flexibility of configuration to meet a variety of installation requirements. The sensor must also provide a high Probability of Detection (P_d) and a very low False Alarm Rate/Nuisance Alarm Rate (FAR/NAR) in order to be effective.

The PINTS consists of a Sensor Electronic Unit (SEU), a stimulus, and a Sensor Transducer Set (STS) (Figure 1). The STS consists of up to four pairs of ported coaxial transmit and receive transducer cables that define the detection zone (Figure 2). The SEU provides the necessary processing electronics to detect intrusions and to interface with the FIDS for power and alarm communications. The stimulus allows the FIDS to effect an end-around test of the sensor.

One of the major features of the PINTS is its configuration flexibility. With up to four independent cable pairs, the PINTS can be configured to provide a variety of optional detection zone geometries. Since the detection zones are defined by the spacing, location, and length of the transducer cables, the PINTS can be thought of as a user-configurable *guided radar* sensor. Major benefits of guided radar operation are:

- Guided detection zone,
- Confined detection zone, and
- User adaptability.

Another key feature of the PINTS is its VHF operation, which provides optimal detection of humans and high rejection of common FAR/NAR sources such as vibration and small animals. The PINTS is capable of operation in the presence of other FIDS sensors without mutual interference.

The PINTS is an international development program jointed funded by the Canadian Department of Regional Industrial Expansion (DRIE) under the US/Canadian Defense Development Sharing Agreement. A joint project agreement has been entered into by the US Army and the Canadian Government. The project agreement identified three development phases for the PINTS program:

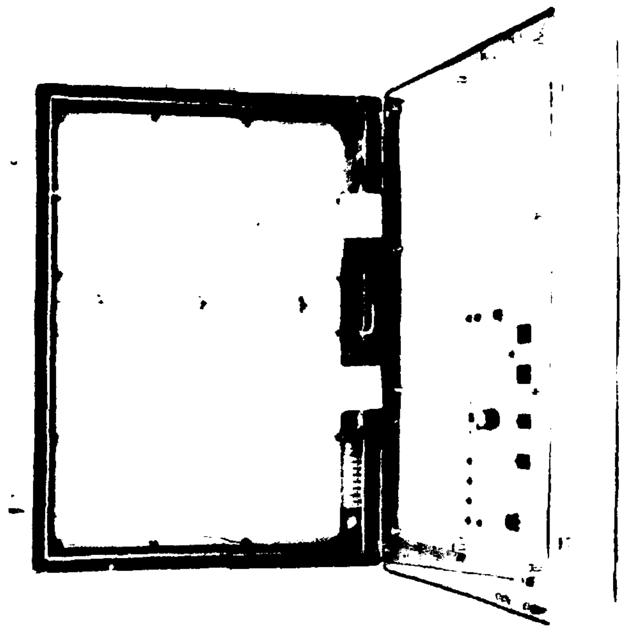
- Phase I - Feasibility Test and Evaluation (successfully completed)
- Phase II - Advanced Development (nearing completion)
- Phase III - Full Scale Development (planned for initiation in FY88 following the successful completion of Phase II).

During Phase I, Engineering Development Testing (EDT) was conducted. During these tests a functional PINTS model and laboratory test equipment were employed. Phase II testing included verification of the PINTS P_d, NAR simulations, and FAR monitoring. These tests were conducted at Fort Belvoir Research, Development and Engineering Center (BRDEC) and witnessed by the US Army Test and Evaluation Command (TECOM) personnel as *Developmental Test - I (DT-I)* utilizing two PINTS Brassboard, Advanced Development Models produced under the Phase II contract. Adversary tests were also conducted at the Center during 1QFY87 and witnessed by TECOM personnel. A Concept Evaluation Program (CEP) test was conducted at Eglin AFB, Florida, during 3QFY87. All of the user representative's (The United States Army Military Police School (USAMPS)) critical issues, as well as non-critical issues, were tested. A review of the test report from the tester (The United States Army Infantry Board (USAIB)) indicates that an excessive FAR precluded the collection of certain required data. Results of the test showed that the high FAR made it difficult to answer the performance issues, but the reliability, availability, and maintainability (RAM) and safety issues were answered satisfactorily. CEP test results were significantly different than test results obtained prior to the CEP test. A subsequent engineering investigation led by the material developer (BRDEC) and conducted in September 1987, identified the causes of the excessive alarm rate. Under the direction of the material developer, the Engineering Investigation Team was organized to determine the cause(s) of the excessive FARs and recommend corrective measures to restore proper performance of the PINTS installed at Eglin AFB.

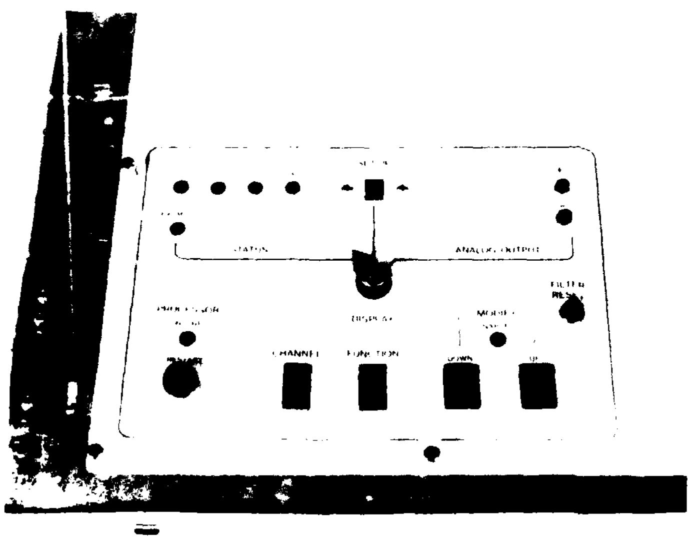
TEST DURATION AND LOCATION

The Engineering Investigation Team conducted an investigation of the PINTS as installed in Building 975 located on Eglin AFB (Eglin Main) during September 1987. The investigation consisted of Electromagnetic Interference/Radio-Frequency Interference (EMI/RFI) testing; examining the sensor electronic unit and transducer cables; and examining the PINTS as deployed in Building 975. The Air Force provided military personnel for system operators, and civilian contract personnel from Radio Corporation of America (RCA) for system installation, maintenance, and data collection. The investigation team of BRDEC, EG&G, and Computing Devices Corporation (COMDEV) identified and individually tested for possible FAR sources. Each of the suspected sources of high FAR were individually isolated and evaluated as follows:

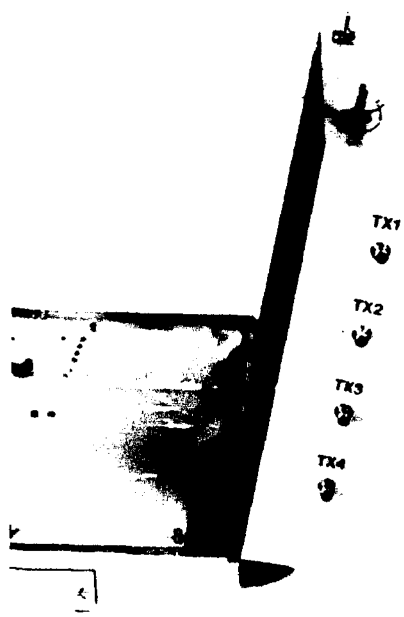
- Sensor hardware integrity
- Internally/self-generated FAR alarms
- External EMI sources
- Local traffic/phenomena near facility outside detection zone.
- Events occurring within the detection zone
- Installation techniques and procedures.



FRONT VIEW



CONTROL PANEL



SIDE VIEW

Figure 1. Sensor Electronic Unit (SEU)

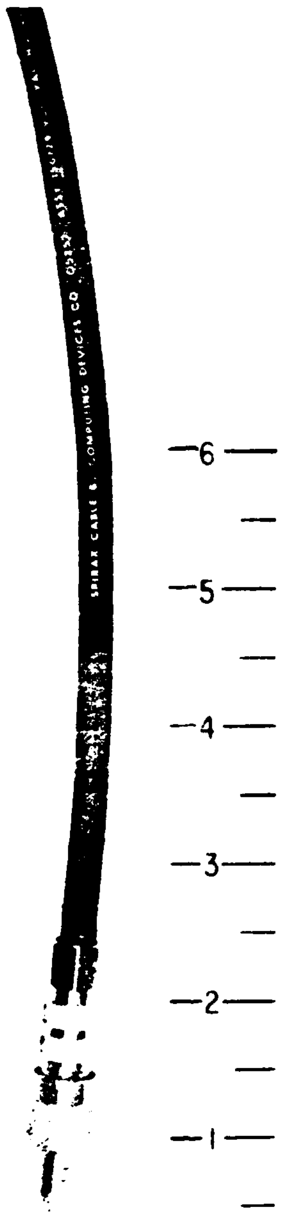


Figure 2. Sensor Transducer Cable

SECTION II. INVESTIGATION

The primary objectives of the engineering investigation were to determine the cause(s) of ... NAR/FAR rate with the exact test setup as was used for the CEP test and to recommend ... measures for enhancing sensor performance in Special Project Facility, Building 975, Site ... AFB

GENERAL TEST DESCRIPTION

The installed PINTS in Building 975 was reactivated with all settings and configuration ... to verify the previously established data baseline. The verification of data baseline was ne... insure identical sensor performance had been achieved. Once the sensor performance was confirmed, the Sensor Electronic Unit (SEU) was tested to confirm proper operation of ... subassemblies. An in depth investigation of the transducer cables was then performed. ... alarm generating mechanisms were identified and examined in detail by the investigation ... tests were accomplished without destroying the original cable configuration ... Site #1, Build... (see Figures 3 and 4).

The PINTS was installed as part of the base security system to protect the Special Project ... Eglin Main. The sensor was interfaced with a FIDS control unit (CU) which was located ... Building 975. The CU was connected to the FIDS console located in the Security Police Headquarters, Building 272.

BASELINE DATA TESTING

Test Description

The first set of data collected verified all settings and that the configuration of the PINTS ... installed during the CEP test. The PINTS was brought on line and monitored with the FIDS ... for a total of 30 hours. RCA personnel provided one stump-sitter (data collector) positioned a... Building 975 and also one stump-sitter located at Building 272. US Air Force personnel as... with the operation of the FIDS console (console operator) and provided hard copy printout ... was collected during this monitoring period. The console operator responded to all test alarms ... keyboard acknowledge only. Data collectors noted all alarms, any sources of outside stimuli ... could have caused an alarm to be generated, and collected the computer printout and weather ... the conclusion of each day of testing. Walk tests were performed to insure that the system ... detect an intruder a minimum of three times during each test period.

The first and second day of testing gave continually recurring false alarms. This data establishe... baseline that was necessary to insure that identical sensor performance had been achieved a... observed during the CEP test.

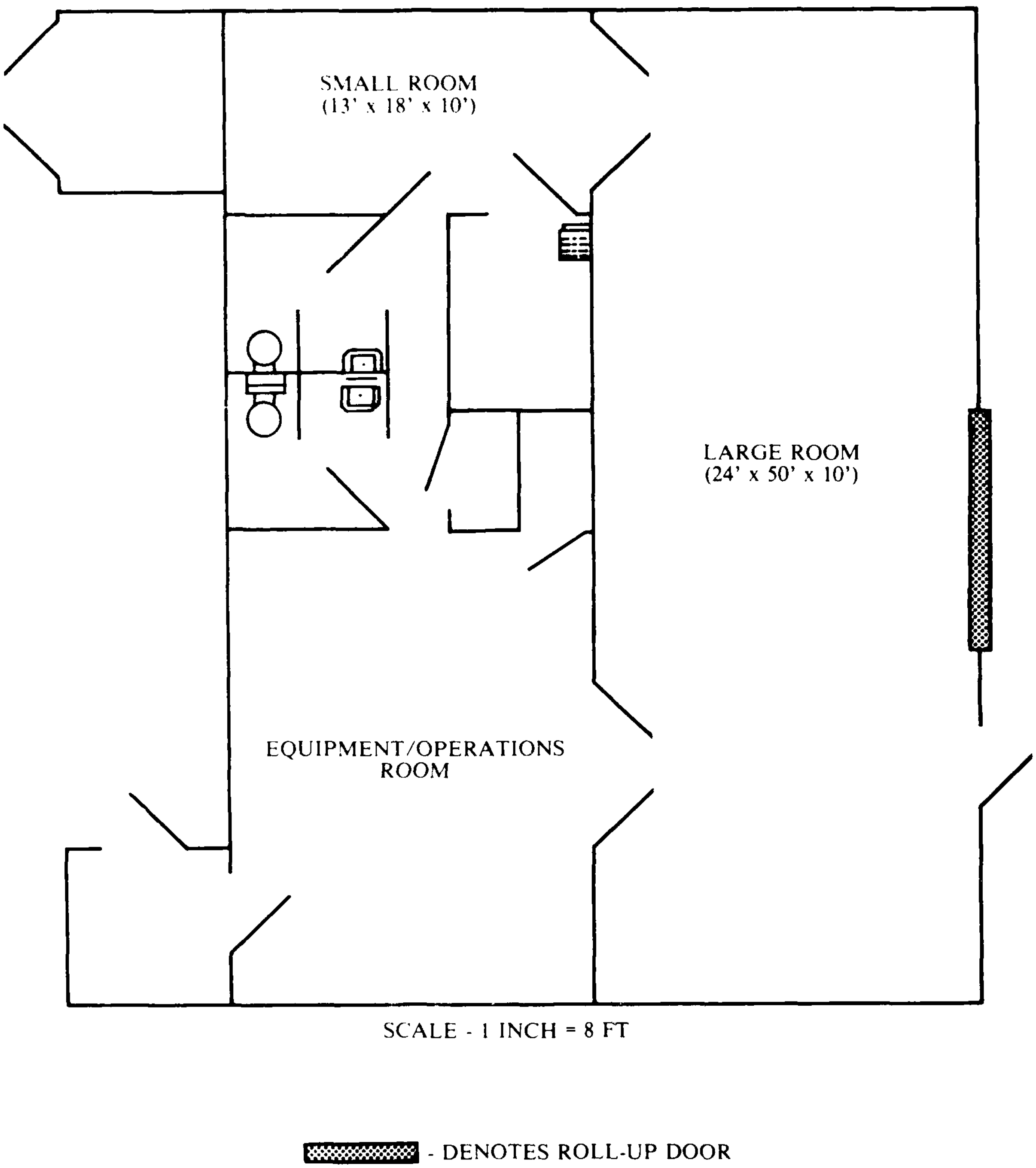
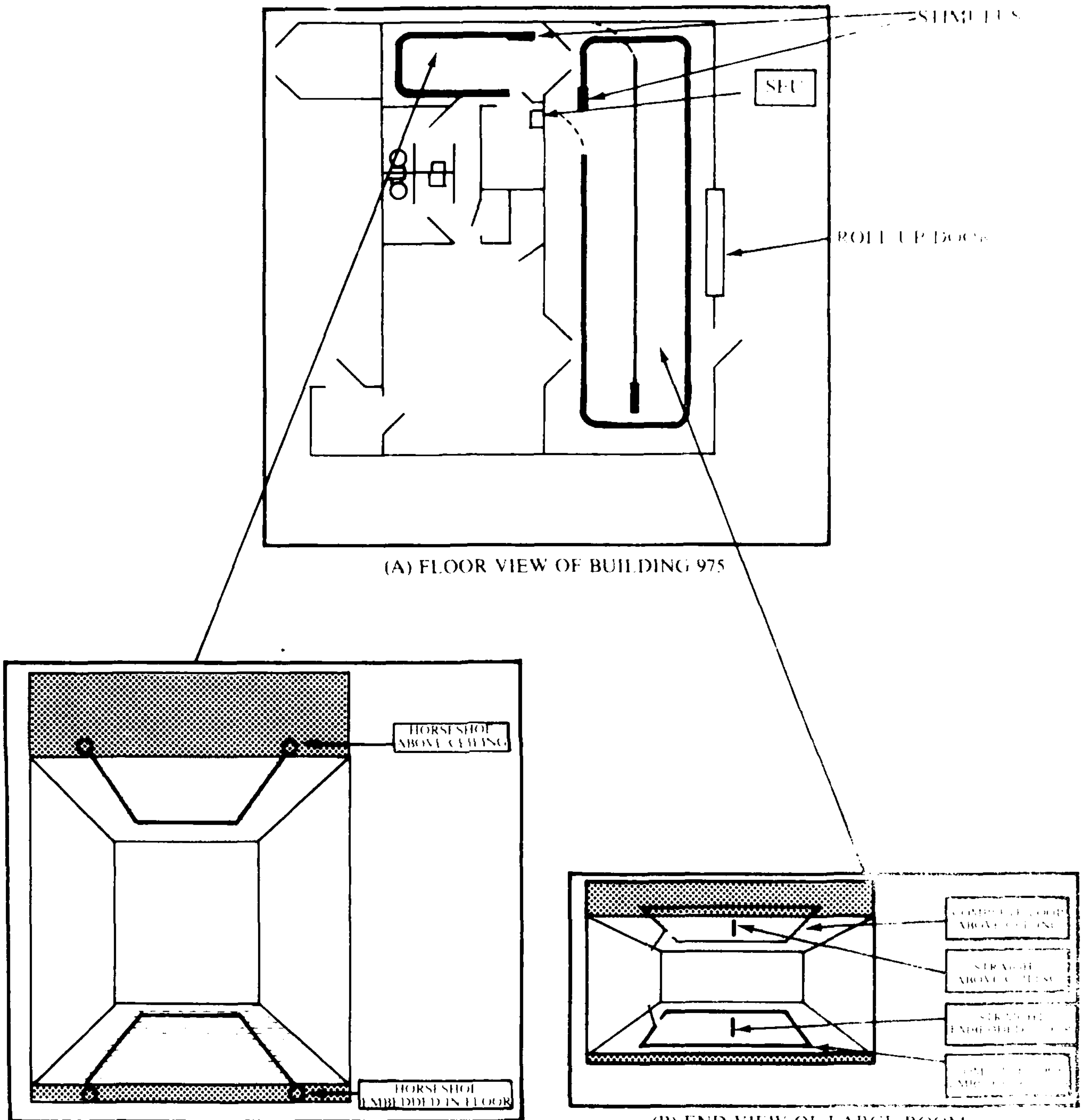


Figure 3. Floor Plan, Building 975, Eglin AFB



(A) FLOOR VIEW OF BUILDING 975

(C) END VIEW OF SMALL ROOM

(B) END VIEW OF LARGE ROOM

NOTE: NOT DRAWN TO SCALE

Figure 4. Original Cable Configuration, Building 975

On the third day of monitoring, the team requested the services of a monitoring EMI/RFI van, equipped with spectrum analyzers and associated RF measuring equipment, to measure and record the EMI/RFI environment at Building 975. Data was collected, using the EMI/RFI van, over a period of several days in an attempt to correlate FAR/NAR alarms to specific spectral activity. A spectrum analyzer was also set up inside the building and Zones 1, 2, and 3 were monitored. Figure 5 shows the original cable configuration for Zones 1 and 2, located in the large room, and Zone 3 located in the small room.

Test Results

During this test period, a significant number of false alarms were observed and logged. All settings were recorded and the original baseline data was verified. Although a significant number of false alarms were observed, no conclusive correlation to external EMI events could be determined. The spectrum analyzer used inside the building demonstrated that the PINTS transmitter was stable during the monitoring period.

SENSOR HARDWARE INVESTIGATION

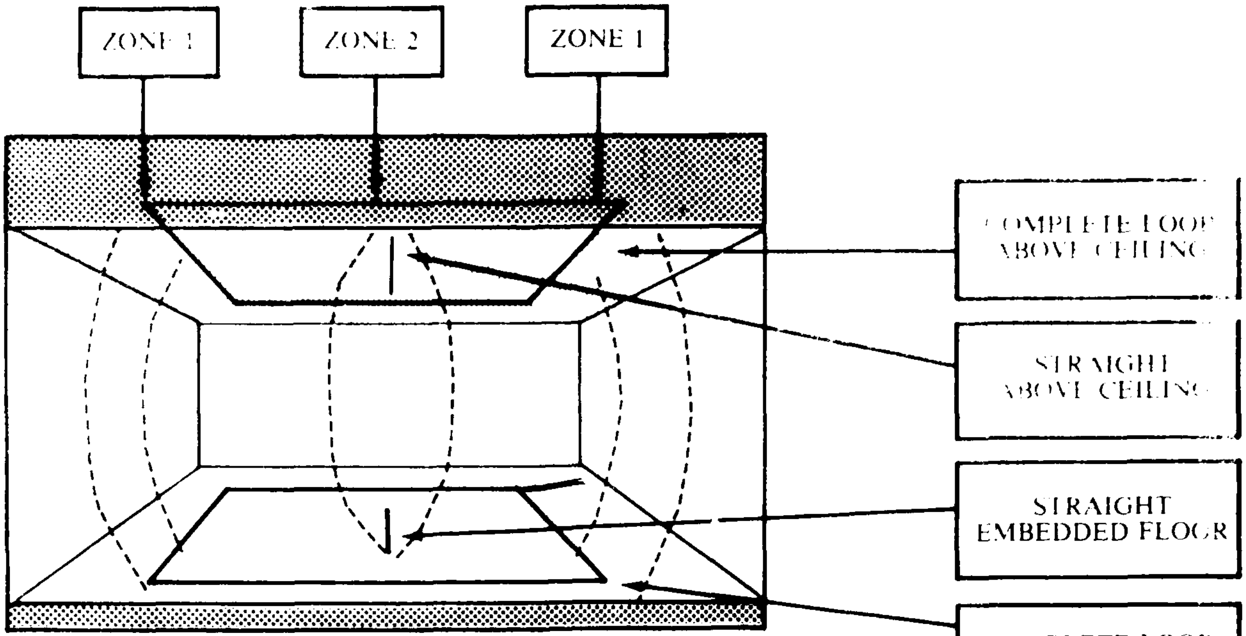
Test Description

An in-depth investigation of the sensor hardware including cables was performed without disturbing the original settings and configurations. The team conducted a visual inspection of the detection zones and the SEU to verify compliance with the original settings and configurations. The installation was inspected by the team for the following types of conditions:

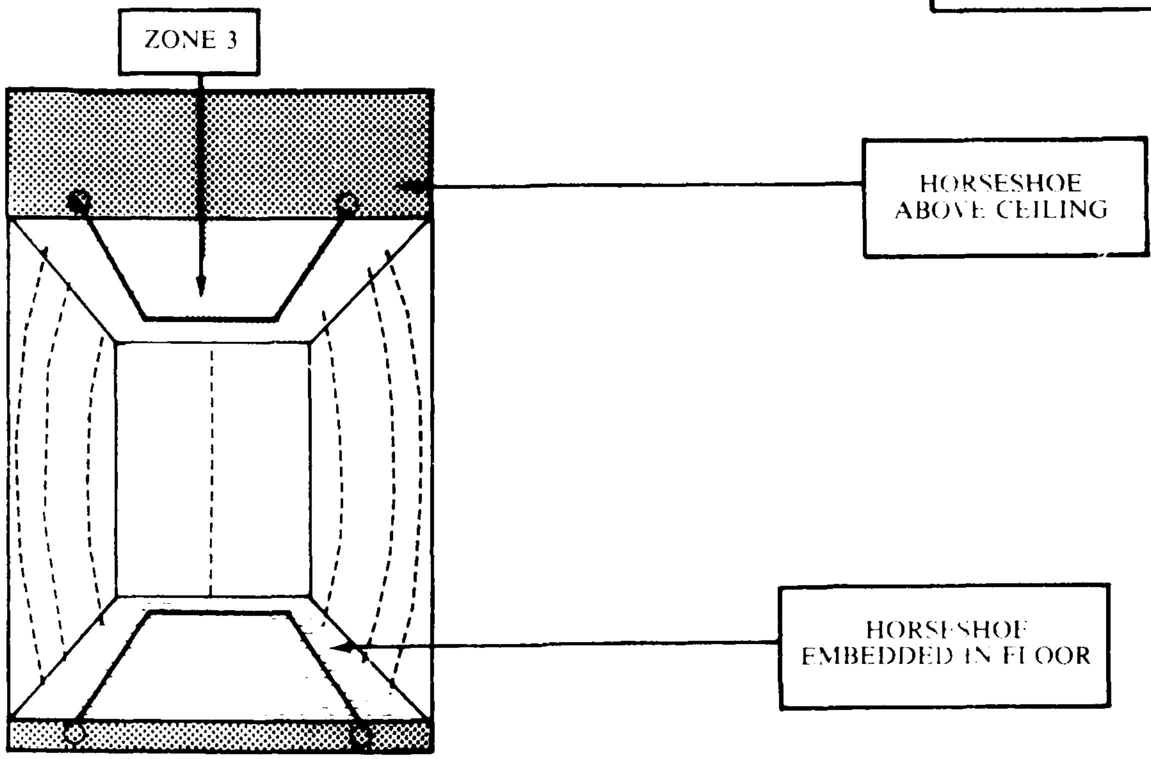
- Suspected cable damage
- Physical change to the SEU
- SEU to CU interconnection damage
- Damage to Stimulus Unit
- Unauthorized changes in the secured area conditions which may have rendered the system ineffective

Test Results

It was found that one cable connector for the receive cable (Rx3), when disturbed or displaced, could cause an alarm. The cable end was cut and repaired with a new connector. The team also discovered that only one of three stimuli (PINTS) was functioning and that the cable pair in the small room, transmit (Tx3) and receive (Rx3) (Zone 3), seemed to be more sensitive than the other cable pairs located in the large room. Stimuli located in Zones 1 and 2 were repaired and operated with a high degree of confidence. Data collected and observed during this test period were recorded



(A) END VIEW OF LARGE ROOM



(B) END VIEW OF SMALL ROOM

Figure 5. RF Field for Large and Small Room

and analyzed by the investigation team. It was decided by the team that the alarms caused by the connector and stimulus did not have a major impact on the high FAR rate. A test for internally self-generated false alarms for the SEU was conducted. The results of this test clearly indicated that the FAR source was not internally or control link generated (see Appendix A).

LOCAL ENVIRONMENT OR PHENOMENA NEAR FACILITY OUTSIDE PINTS DETECTION ZONES

Test Description

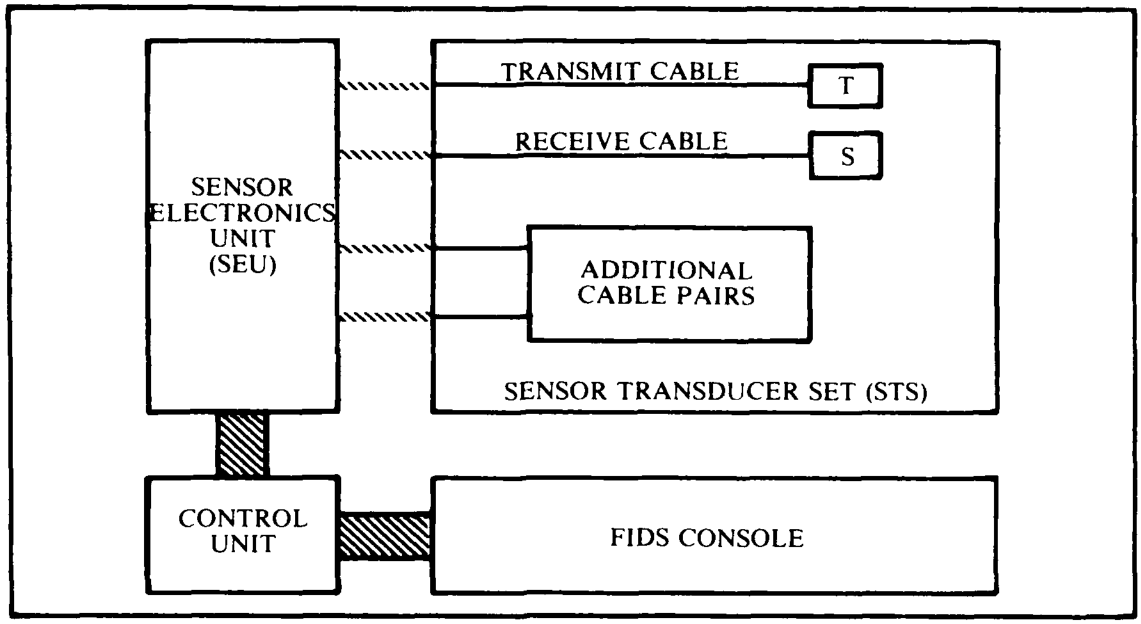
This test consisted of generating and monitoring external events outside the building such as human activities (movement), aircraft taxiing nearby, vehicular traffic, and the movement of various building structures. The purpose of this test was to correlate these activities with alarm occurrences. Stump sitters were stationed outside the building with two-way radios to monitor the outside events and to relay the status of the events to the stump-sitters on the inside of the building. Human activities such as mowing the grass, walking and running around the building, tapping on the outer walls, doors, and vents, were conducted. Several vehicles of different types were used to drive around the building and on the local access road. Several hours of data were collected from aircraft traffic on a nearby taxiway. The opening and closing of exterior and interior doors was also performed as part of this test in an attempt to create nuisance alarms. A simulated external intentional jamming of the PINTS was performed by using an RF signal generator and antenna. Antennas were located outside and inside of the test facility.

The first part of this test was conducted with the PINTS interfaced to the FIDS console and the later part was conducted with the PINTS connected to the FIDS simulator (see Figure 6). Most of the data collection during this investigation was accomplished with the PINTS interfaced with the FIDS Simulator. The PINTS FIDS I/O Simulator (FIDSIM) is a piece of test equipment designed for testing and proving the design of the PINTS.

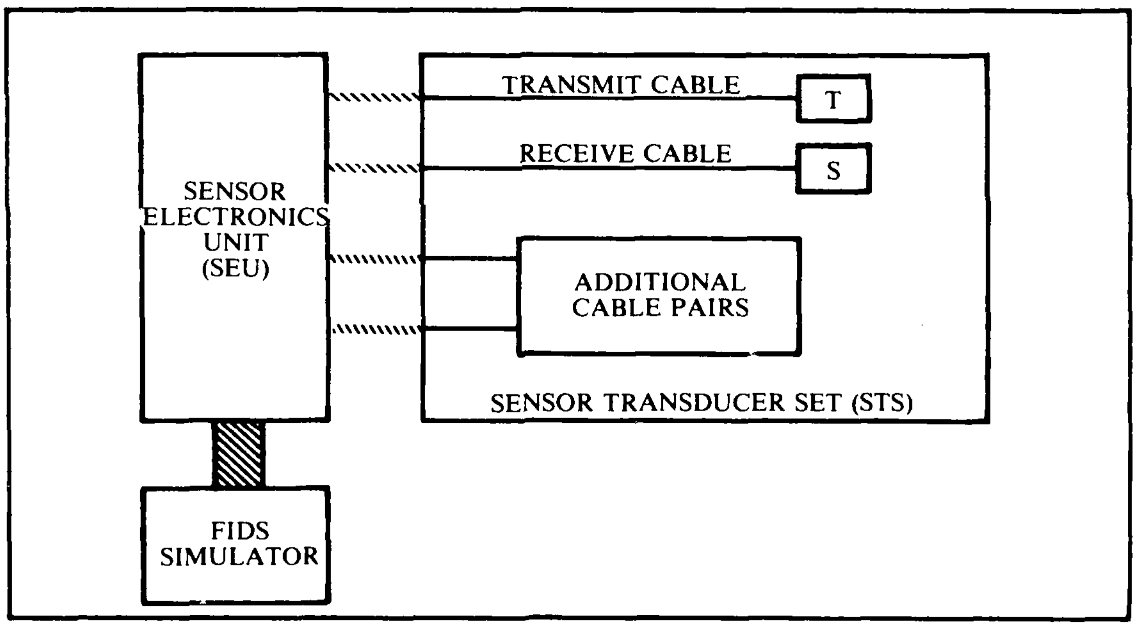
Analog data were collected and stored on an analog chart recorder. A four-channel analog recorder was used to tape the analog signal from the test port of the FIDSIM. The FIDSIM was connected internally to the PINTS electronics units which allowed the PINTS to communicate with the FIDSIM directly.

Test Results

Several events were performed and monitored in an attempt to correlate the external local environment or phenomena near the test site to FAR/NAR alarms Most of the events and activities were performed during the day and stump-sitters (data collectors) were provided for monitoring the local environment during non-duty hours. Data collected during overnight monitoring were analyzed and evaluated the following day. All data collected were analyzed and evaluated by the investigation team.



(A) **PINTS** INTERFACED WITH CONTROL UNIT AND FIDS CONSOLE



(B) **PINTS** INTERFACED WITH FIDS SIMULATOR

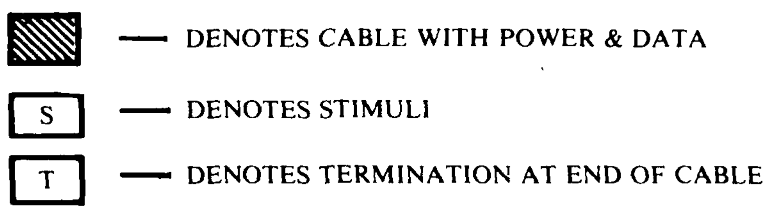


Figure 6. Major Functional Components of the PINTS and Interfaces

... hours of NAR data were obtained during this test period which included high wind and ... rainfall. Neither simulated nor actual events consistently produced alarms. A review of the ... by the investigation team revealed little or no correlation between external environmental ... or phenomena to FAR/NAR alarms. Therefore, it was concluded that local external ... phenomena were not the major cause(s) of the high FAR/NAR.

... ENVIRONMENT OR PHENOMENA WITHIN DETECTION ZONES

Description

PINTS detection zones for Building 975 were located in two rooms. The original configuration ... of Zones 1 and 2 located in the large room, and Zone 3 located in the small room. The transmit cables for each zone were located above a suspended metallic ceiling structure (see Figure 7). The receive cables, for the original configuration, were embedded in the concrete floor. The PINTS was connected to the FIDSIM for power and data communication during this test. The analog chart recorder was also used for data collection and storage.

The first series of tests involved reversing the transmit and receive cables (Tx reversed to floor and Rx reversed to ceiling). This procedure was accomplished by reversing the transmit and receive cables at the SEU for all zones. Data was collected with the reversed cable set up to include day and night monitoring and detection for human intruders. The investigation team reviewed the data and determined that there was no major change in the FAR rate and detection capability. Since no major change in performance was noted, the cables were reversed to their original configuration.

The second series of tests involved gathering data from a controlled and stable environment. The detection zones in the large room were reconfigured (see Figure 8). The new transmit (Tx1) cable was the center cable embedded in the floor and the new receive (Rx1) cable was the outer perimeter embedded in the floor. Several causes of false alarms were postulated by EG&G (see Appendix B) and are listed below:

- The introduction, removal, or change in length of any electrical conductor within the PINTS RF field will disturb the field and cause a change in the RF energy received by the PINTS. These conductors act as passive antenna elements (Antenna Effect). If the energy change were large enough, the PINTS would be expected to alarm.

- Electrical noise (EMI) may have been a cause of the false alarms.

- Large, unbalanced current flows can affect the magnetic properties of nearby ferromagnetic materials, changing their permeability (for example, steel conduit protecting AC wiring). If the ferromagnetic materials were within the PINTS RF field, then varying load currents could produce a varying effect on the PINTS RF field.

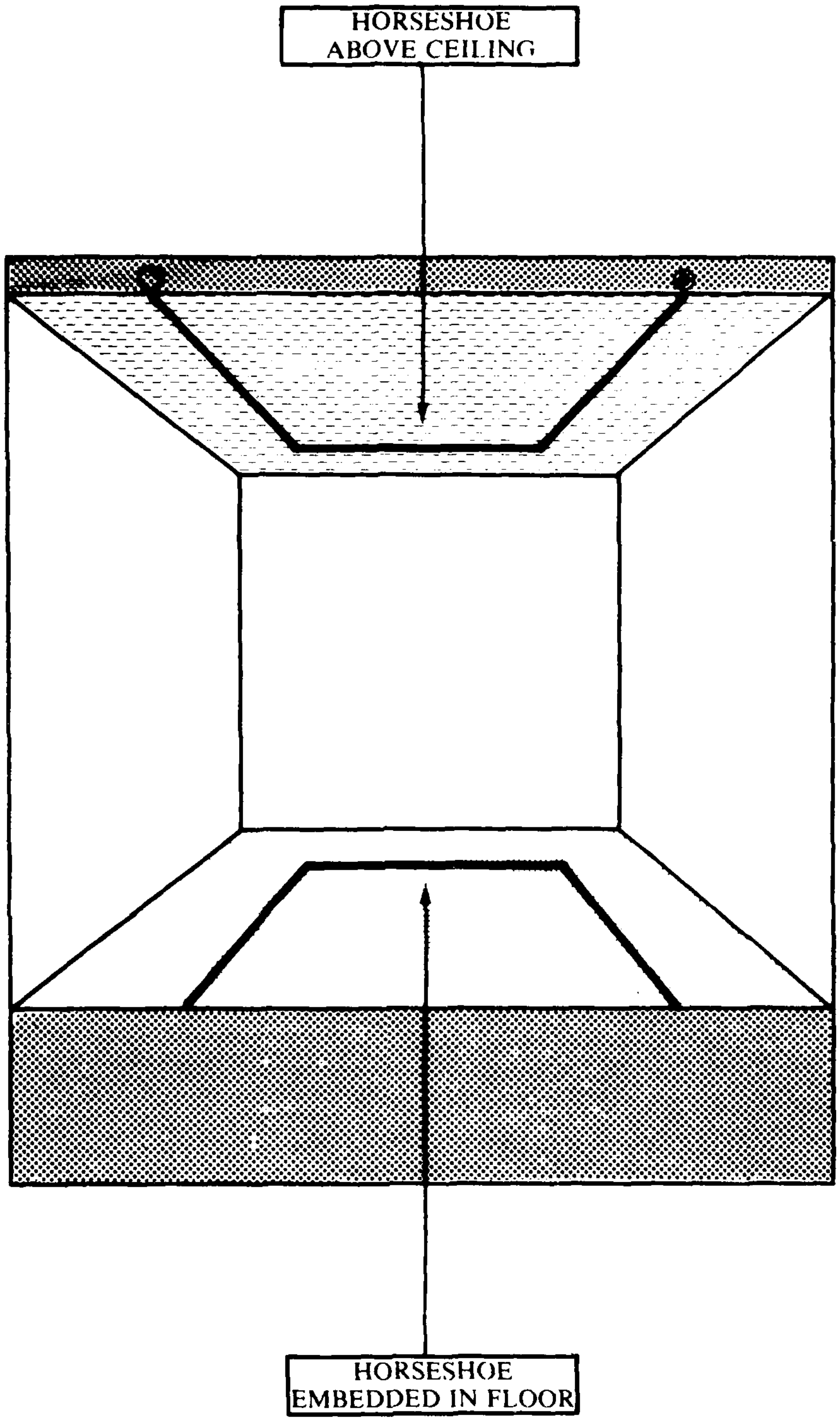
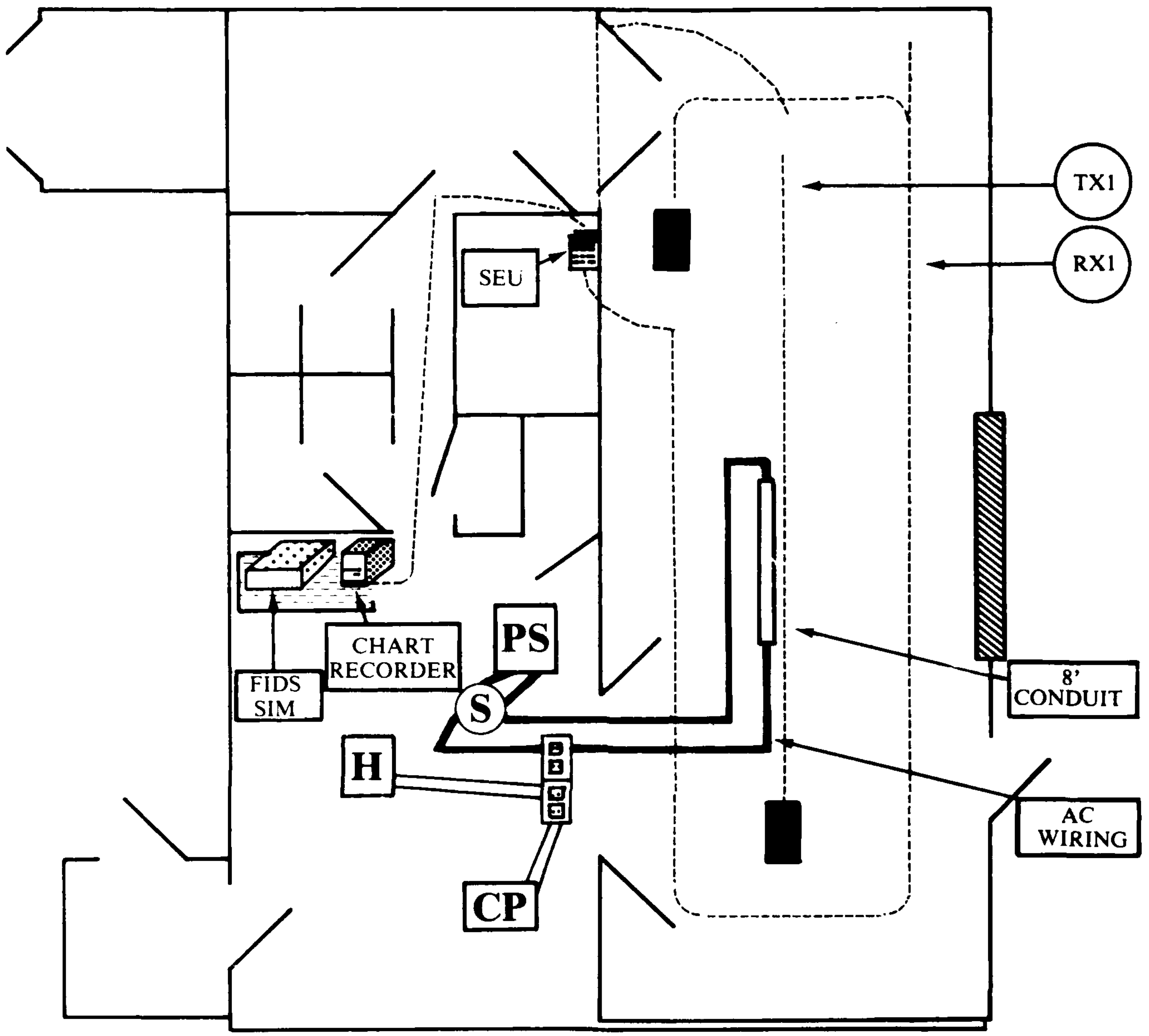


**Figure 7. Transmit Cables Above Suspended Ceiling
Receive Cables Embedded in Concrete Floor**



SCALE - 1 INCH = 8FT

- DENOTES ROLL-UP DOOR
- DENOTES STIMULI
- AC STRIP

H - HEATER
PS - POWER SUPPLY
CP - COFFEE POT
S - SWITCH

Figure 8. Controlled Environment Setup in Large Room

Various tests were conducted with the new configuration to demonstrate the possible phenomena that could cause(s) the unpredictable high FAR rate. These tests are covered in depth in Appendix B.

Test Results

The new cable configuration (the floor pair) proved to be the most stable configuration achieved and was monitored undisturbed for a total of 84 hours (see Table 1). During this monitoring period, only one false alarm was observed and recorded.

Table 1. Analog Output Noise Comparison Chart

NOISE LEVEL COMPARISON BETWEEN ZONES 2, 3, AND 4 OF SMALL ROOM, BUILDING 975, EGLIN AFB, FLORIDA

	ZONE 3	ZONE 4	ZONE 2
RECORD NUMBER	Rx 16" FROM CEILING (mV)	Rx 4' FROM CEILING (mV)	Rx 7' FROM CEILING (mv)
1	40	120	570
2	20	20	60
3	50	20	1
4	80	60	1
5	60	1	40
6	150	60	40
7	80	10	20
8	200	40	20
9	130	60	40
10	90-100	40	1-10
11	80	80	20
12	140	20	40
13	360	20	40
14	140	100	40
15	220-420	20-50	10-40
16	200	90	40
17	240	40	30

NOTE: Transmit cable: Horseshoe configuration embedded in floor

mV = millivolt
Rx = receive cable

There were at least two possible sources of the Antenna Effect present in Building 975. The first was the suspended-grid ceiling, and the other was electrical equipment wiring such as switches, thermostats, and telephone equipment. All of these sources were located within the PINTS RF field. The Antenna Effect was found to be a very significant problem. The installation of the PINTS cable caused the suspended ceiling to be the primary contributor to the Antenna Effect (see Figure 7). It was constructed of hundreds of metallic elements, each approximately 2 feet in length, and each capable of making electrical contact with other elements. The PINTS 60MHz carrier frequency has a corresponding wavelength of 16 feet and a 2 foot conductor (one-eight wavelength) could easily perform as an antenna element. The team conducted several experiments to produce a force on the ceiling in an attempt to cause the PINTS to alarm. The investigation team had great success in causing the system to alarm by applying very small forces to the ceiling. Normal temperature and pressure changes could also exert a small force on the ceiling which could cause the system to alarm. Electrical appliances or AC wiring to such appliances within the PINTS RF field were observed to cause alarms when the appliances' thermostats changed state, whether or not AC power was applied. Also, telephone equipment within the PINTS RF field was observed to cause alarms. Telephone equipment included line-connect relays which, when actuated, changed the lengths of many conductors in the building.

ISOLATION OF CEILING FROM DETECTION ZONES

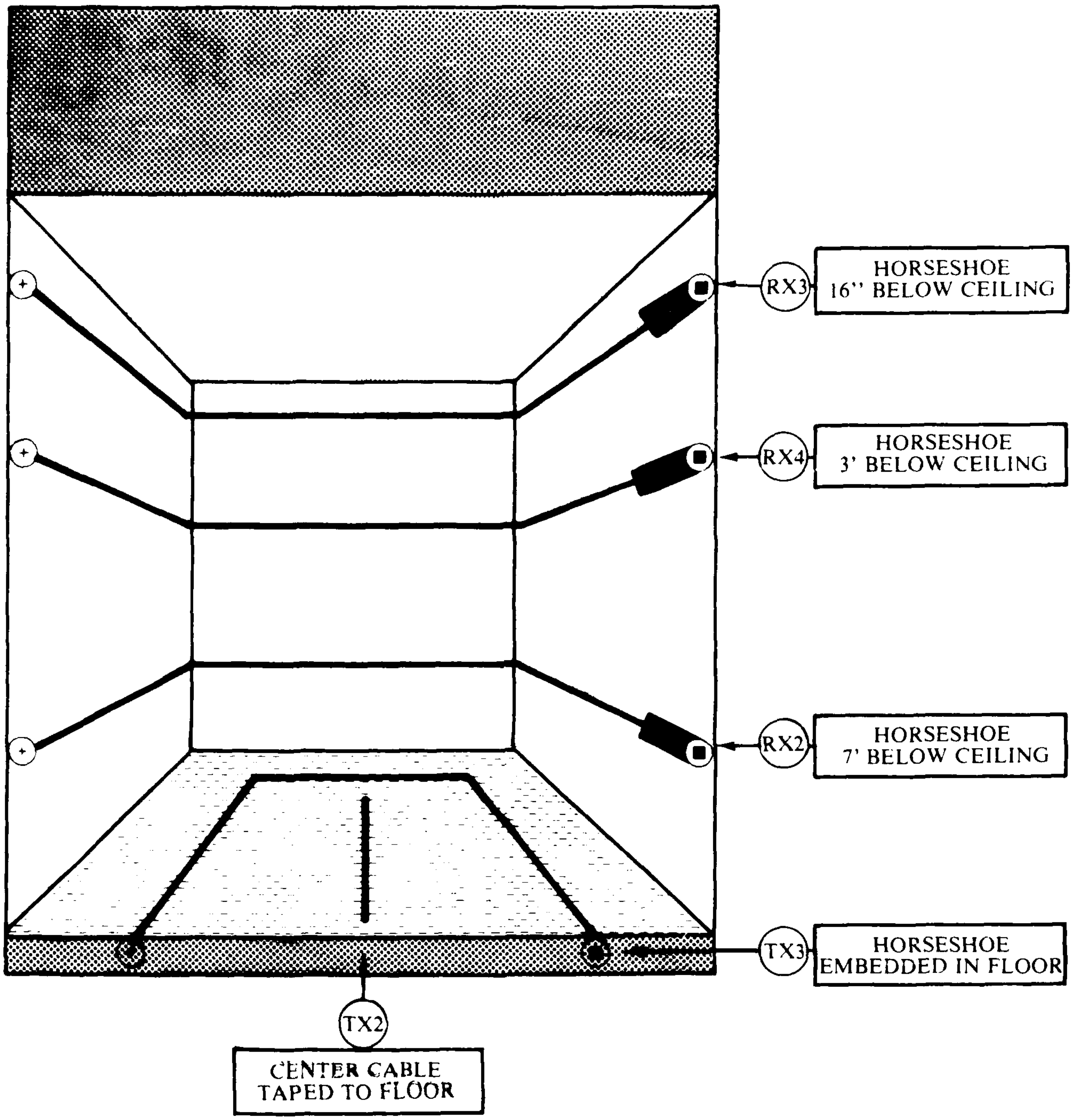
Test Description

After extensive data collection and analysis, it was determined by the investigation team that the most significant cause of the high FAR/NAR rate was due to the Antenna Effect in which the suspended ceiling was the major contributor. An attempt was made by the team to isolate the detection zones from the suspended ceiling. The following are the different zone configurations used in an attempt to isolate the detection zones from the suspended ceiling:

1. The first configuration was to create a detection zone inches below the suspended ceiling. A new receive cable (Rx3) was taped to the walls in the small room 16 inches below the suspended ceiling (see Figure 9). Transmit cable (Tx3), embedded in the floor in the small room, was remapped to communicate with Rx3. This pair was referred to as Zone 3.

2. The next configuration was to deploy another cable approximately 3 feet below the suspended ceiling. This receive cable (Rx4) was taped to the walls in the small room. Tx3 was also used to communicate with Rx4 (see Figure 9). This cable pair was referred to as Zone 4.

3. The third configuration was to create a zone approximately 1 foot from the floor. Receive cable Rx2 was taped on the walls approximately 7 feet from the ceiling in the small room. A new transmit (Tx2) cable was also taped to the floor in the small room and was mapped to transmit to Rx2 as Zone 2 (see Figure 9).



ZONE 3 - RX3 AND TX3
ZONE 4 - RX4 AND TX3
ZONE 2 - RX2 AND TX2

Figure 9. Small Room Cable Configuration

4. The final configuration that was deployed in the small room was a floor pair. Transmit cable (Tx2) was taped to the floor and was remapped to communicate to receive cable (Rx3) embedded in the floor (see Figure 10). This pair created a new Zone 2 in the small room.

5. The final configuration designed for the large room was also a floor pair. A new cable was installed parallel to the embedded perimeter as receive cable (Rx1). The embedded cable in the center of the room was remapped to receive cable (Rx2). Rx1 was taped approximately 2 feet toward the center of the room from Tx1 (see Figure11). Transmit cable #1 (Tx1) was the embedded perimeter cable. Tx1 and Rx1 was Zone 1, and Tx1 and Rx2 became Zone 2.

FAR/NAR and intrusion data were collected from the wall pair cables (Zones 2, 3, and 4) simultaneously in the small room. A comparison of the analog output was made of the collected data (see Table 2).

In addition to the FAR sources already identified, the team also investigated alarms that were occurring in the vicinity of the small room, and appeared to be due to a very sensitive HOT, lead-in. An electric hand drill was used in an attempt to isolate the problem. The electric hand drill, placed about 12 inches from the PINTS SEUs, caused alarms on several zones in the small room. Several different measurements were taken with the hand drill in the protected zones in the small room. As the drill approached the SEU, the analog response increased for the detection zone.

Test Results

All data was analyzed and evaluated by the investigation team. A comparison chart was compiled to compare the collected analog output data obtained from the floor and wall cable pairs. Data collected during this testing series supported the theory that the suspended ceiling was the main contributor to the high FAR rate. The analog output readings collected during the monitoring period for the same event, seemed to be much lower for the cable zones farther away from the suspended ceiling (see Figure 13). Also, in accordance with data collected, the floor pair exhibited greater stability than any other configuration tested. A floor pair was designed for the small room and only one false alarm was reported during this test period. The floor pair configured for the large room reported no false alarm during the monitoring periods. The response to human motion (in terms of analog output) was much greater, and floor coverage for the room was greatly improved. COMDEV consulted with the designer of the PINTS cables and concluded that the HOT lead-in problems associated in the small room were likely arising from field coupling mechanisms that effectively made the lead-in HOT (sensitive) and extended the detection zone outside the room, thus allowing other sources, such as the water cooler and air conditioner, to generate alarms. Ferrite beads were used to deaden the HOT lead-in on the cables. The HOT lead-in problems only existed in the small room.

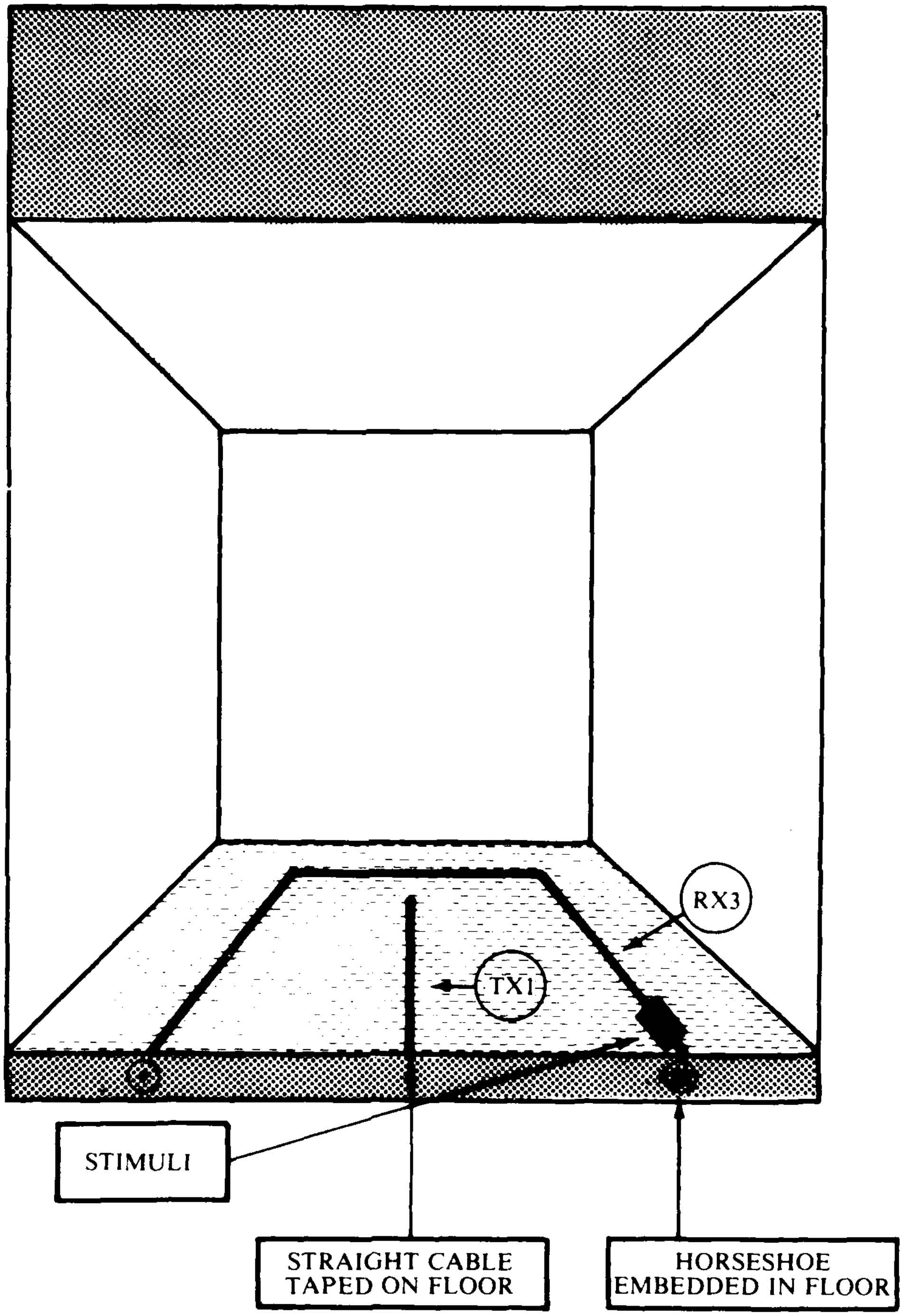


Figure 10. Floor Configuration for Small Room

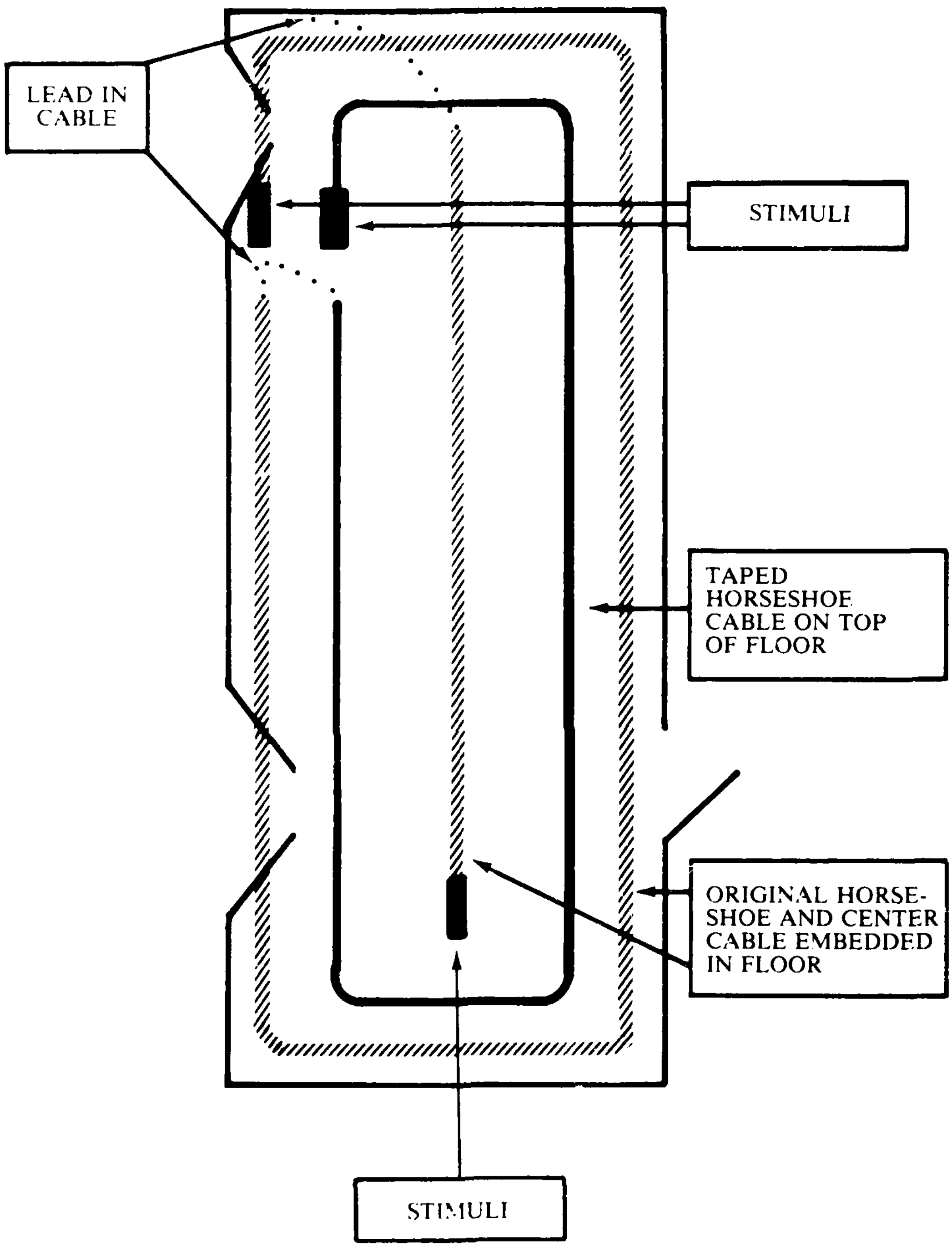


Figure 11. Final Floor Configuration for Large Room

Table 2. Data Collected for Different Cable Configurations for Large and Small Rooms

LARGE ROOM ALARM DATA

CABLE ARRANGEMENT Tx - Rx	HOURS	ALARMS	MAXIMUM BACKGROUND (mV)	SEU THRESHOLD (mV)
Center Ceiling-Center Floor	20.5	0	180	300
Center Floor-Center Ceiling	66.5	0	240	300
Horseshoe Ceiling-Horseshoe Floor	20.5	0	570	898
Horseshoe Floor-Horseshoe Ceiling	66.5	0	460	989
Center Embedded-Horseshoe Embedded	84.5	1	< 20	35
Horseshoe Embedded-Horseshoe Taped	27	0	< 5	100
Horseshoe Embedded-Center Embedded	27	0	< 5	100

SMALL ROOM ALARM DATA

CABLE ARRANGEMENT Tx - Rx	HOURS	ALARMS	MAXIMUM BACKGROUND (mV)	SEU THRESHOLD (mV)
Horseshoe Ceiling-Horseshoe Embedded	20.5	6	690	798
Horseshoe Embedded-Horseshoe Ceiling	147	28	760	798
H/S Embedded-Wall 16" Front Ceiling	171.5	46	360	400
Center Taped-16" Front Ceiling	13.5	4	140	200
Center Taped-Horseshoe Taped	80.5	2	170	200
Center Taped-Horseshoe Embedded	44.5	0	< 20	200-300
Horseshoe Embedded-Center Taped	26.5	0	100	200
Floor Pair Taped (Parallel)	14	0	< 10	200
Center Taped-Wall 7' Front Ceiling	37.5	3	180	200
H/S Embedded-Wall 4' Front Ceiling	37.5	0	150	300
H/S Embedded-Wall 7' Front Ceiling	13	0	40	200
Total		89		

NOTE: Floor pair yielded lower noise and reduced false alarm rate for Building 975, Eglin AFB, FL.

mV= millivolt
H/S = Horseshoe

SECTION III. CONCLUSIONS AND RECOMMENDATIONS

A series of tests were performed which included moving and replacing cables to confirm a significant source of the false alarms could be attributed to the suspended ceiling within the detection zones. AC wiring, leading to electrical appliances within a building and within the PINTS RF field whose length changes upon relay or thermostat activation, could cause a major problem for the system if not installed properly. The "Antenna Effect" and the "HOT" lead-in problems were related to the installation of the system. With the development of a Selection, Application and Installation Guide (SAIG), to include PINTS, this problem could have been resolved or greatly reduced. A continued effort is recommended to collect intrusion data for the system including false and nuisance alarm signatures to enhance the PINTS data base. The following conclusions are supported by the PINTS data base:

1. The sensor performance is very dependent on proper installation.

2. The sensor is capable of good detection performance with low NAR/FAR when installed in a "quiet" environment such as bunkers, igloos, and magazines.

3. The sensor cable geometry (tight cable bends) driven by small room size is not conducive to good sensor performance.

4. The "Antenna Effect" influence on NAR/FAR can be minimized by proper installation and application of the sensor.

5. For properly selected sites and correctly installed systems, PINTS performance will meet or exceed requirements, and become a formidable new sensor in the Advanced FIDS sensor program.

It is recommended that:

1. Extensive additional testing be performed to fully characterize performance, capabilities, and limitations.

2. Collected knowledge based on different installations be considerably expanded.

Based on the test results and a study of operational considerations, it was determined that the PINTS concept is feasible and practical. This report has been an attempt to summarize the engineering investigation and testing to date of a new interior intrusion detection sensor being developed for tri-service applications. All testing demonstrates that the PINTS offers the potential for performance and operational benefits currently not available from any other interior sensor. The PINTS is expected to significantly contribute to the repertoire of the FIDS sensor family.

APPENDIX A

INVESTIGATION OF PINTS-II PERFORMANCE AT EGLIN AFB, FL.

EG&G Energy Measurments, Inc. - Kirtland Operations

17 November 87

1. Introduction

PINTS-II is a ported-coax interior intrusion sensor which is currently under development for Belvoir Research, Engineering and Development Center (BRDEC). The development contractor is Communications Devices Corp. (ComDev), a Canadian subsidiary of Control Data Corp.

Earlier this year, tests were conducted c two PINTS-II installations at Eglin AFB, Florida, as part of the Concept Evaluation Program (CEP). Significant performance pro s were noted during the test (numerous false or nuisance alarms . Because of EG&G's knowledge and previous experience with this sen bsequent to the test BRDEC requested that EG&G visit Eglin AFB to examine the PINTS-II sensor, installation, and environment, and attempt, retrospectively, to determine the causes of the CEP test problems.

As a result of this examination, EG&G noted several significant findings, which are detailed below. It should be pointed out, however, that these findings are based upon

measurements and experiments performed at the Eglin AFB test site and, therefore, were not closely controlled laboratory procedures. In addition, these investigations were conducted several months after the CEP tests, during which time the equipment and environment had changed.

2. Site visits

EG&G personnel visited Eglin AFB August 31 - September 1, 1987, and again September 15 - September 25, 1987. Although two PINTS-II sensors had been included in the CEP test, only one - installed in Bldg. 975 - was still in place during this period. This particular sensor was reported to have been the most troublesome during the CEP test, and was thus a reasonable object for investigation.

Personnel from BRDEC and ComDev were also on site during the investigation period, and participated in the data gathering and experimentation.

3. Field tests and experiments

On the first visit to Eglin AFB, EG&G personnel verified that the PINTS-II in Bldg. 975 was still operational, and still produced numerous false or nuisance alarms. The alarms were unpredictable but frequent, sometimes as often as every two or three seconds.

Based upon the field observations, several possible causes were postulated. These are listed below.

a. The introduction, removal, or change in length of <u>any</u> electrical conductor within the PINTS-II RF sensing field will disturb the field and cause a change in RF energy received by the PINTS-II. Such conductors act, in effect, as passive antenna elements. If the energy change were large enough, the PINTS-II would be expected to alarm.

At least two possible sources of this "antenna effect" were present in Bldg. 975: a suspended-grid ceiling, and electrical equipment wiring (switches, thermostats, telephone equipment) within the PINTS-II RF fields. The suspended-grid ceiling was a typical 2' x 4' formed-metal grid suspending fiberglass ceiling tiles.

The individual metal sections of the grid were in physical contact, and would be expected to produce random and intermittent (due to accidents of manufacture and corrosion) electrical connections between the elements.

b. Electrical noise (EMI) may have been a cause of false alarms.

c. Large, unbalanced current flows can affect the magnetic properties of nearby ferromagnetic materials, changing their permeability. A possible example would be AC wiring in conduit. If the ferromagnetic materials were within the PINTS RF field, then varying load currents could produce a varying effect on the PINTS RF field.

EG&G, ComDev and BRDEC personnel conducted series of field tests and experiments to try to isolate and identify the above effects. These tests are documented and explained in detail, with accompanying data, in EG&G field notes. Due to the limited time for preparation, and the very severe constraints imposed by the field environment, the tests were not at all rigorous, and did not always produce conclusive results. Nevertheless, at

least one clear pattern emerged, as explained below.

3. Results of field tests.

a. The "antenna effect".

This was found to be a very significant problem. The suspended ceiling was the primary contributor. As noted above, the ceiling's metal grid is constructed of hundreds of metal elements, each approximately two feet in length, and each capable of making unpredictable electrical contacts with neighboring elements. The PINTS-II uses a carrier frequency of 60MHz, with a corresponding wavelength of 16 feet. A two foot conductor (one-eight wavelength) can easily act as an antenna element.

Very small forces applied to the suspended ceiling (using a wooden broom handle) reliably produced alarms. The ceiling could easily be expected to experience such forces due to normal temperature and pressure changes throughout the day.

Electrical appliances (floor heater, etc.), or the AC

wiring to such appliances, within the PINTS-II RF field were observed to cause alarms when the appliances' thermostats changed state (i.e., from open to closed or vice-versa) whether or not AC power was applied.

Nearby telephone equipment within the PINTS-II RF field was also observed to cause alarms. This equipment included line-connect relays, which, when actuated, changed the lengths of many conductors in the building.

b. EMI effects.

With the limited resources available in the field, there was no conclusive evidence for EMI-induced alarms. It was very difficult to devise an EMI experiment that was not also strongly, or overwhelmingly, influenced by "antenna effects" associated with the intended EMI source.

The suspicion exists, however, and futher testing in a laboratory environment is indicated.

c. Secondary mag... effects.

Once again, due to limited field resources and the overwhelming influence of "antenna effects", tests for secondary ma... effects were inconclusive.

4. Conclusions

The PINTS-II sensor, as noted in tests prior to the CEP test, is capable of excellent detection performance with essentially no false alarms, when installed in a quiet environment such as a bunker or "igloo". The CEP test installation in Bldg. 9.. provided a much more difficult environment.

The field investigation was very limited in scope and imprecise in character; however, some definite inferences can be drawn about the PINTS-II performance.

The suspended ceiling was the most likely cause of the numerous false alarms reported during the CEP test. Given the powerful, yet unpredictable influence of the ceiling, it is difficult to envision a successful PINTS installation in Bldg. 9..

Electrical equipment and appliances also may have contributed to the CEP test problems. In any case, they are serious potential sources of alarms. Eliminating their effect would require complete shielding of the appliances and wiring, and controlling their use within an area protected by PINTS-II.

Eliminating antenna effects from the environment may be possible; however, it would certainly necessitate significant front-end effort at each site. A careful, competent site survey would be required; the surveyors would need to understand the principles involved, since some of potential "antennas" could be very subtle (metal cases, hidden thermostats, hidden wiring, adjacent metal objects that might intermittently touch). Considerable effort would be required to remove or shield such antennas.

5. Further comments.

It is possible that some of the difficulties encountered at Eglin AFB might be remedied by changing the either the physical environment, the PINTS-II design, or both. As noted above, the requisite changes to some environments would appear to be very costly. Other environments, such as bunkers, might require little or no change.

Changes to the PINTS-II design, particularly the software processing, might allow recognition of intruder "signatures", and thus improve rejection of false alarms. Preliminary discussions indicate that this may be difficult to achieve without introducing vulnerabilities. Further research on this subject is indicated.

During the field investigation, very little consideration was given to the intrusion-detection performance of the PINTS-II. Due to the high false alarm rate, the sensors' alarm thresholds were set to levels that were unreasonably high (i.e., insensitive) from a intrusion-detection viewpoint. Levels of 300mV to 900mV were apparently used during the CEP test. Previous experience indicates that levels under 100 mV are necessary for proper detection. Thus, the detection performance during the CEP test was driven by false alarm concerns, and is not at all indicative of PINTS-II detection capabilities.

The PINTS-II sense cable geometry utilized in Bldg. 975 has been questioned by ComDev. It does not appear to lie within fully characterized performance boundaries. In particular, tight cable bends and small room dimensions are known to affect the PINTS-II detection performance.

Based upon discussions with COMSEV, it would appear [illegible] great deal more work needs to be done in [illegible] [illegible] [illegible] in a wide range of [illegible] [illegible]. This would be a prerequisite to [illegible] [illegible] selection and application [illegible].

The [illegible] is a sophisticated sensor, capable of impressive performance in the proper environment. Its principle of operation is different from any of the other FIDS sensors, and would thus be useful in a multi-technology approach to protect [illegible] critical assets. The present shortcomings, however, may require extensive site preparation or further engineering of the sensor.

In any case, a good deal more testing is needed to [illegible] characterize the performance of the MINTS [illegible] in a variety of geometries and environments.

APPENDIX B

Test Results Investigation

for the

FINTS Installation

at

Eglin Air Force Base

7 December, 1987
Security Systems Division
COMPUTING DEVICES COMPANY

EXECUTIVE SUMMARY

Although results obtained at the Eglin Air Force base test facility initially failed to achieve expected levels of FAR performance, the subsequent Engineering Test Results Analysis and many hours of detailed additional testing, the source of the high FAR problem has been positively identified, and performance again confirmed.

With the FAR alarm source identified, and with the benefit of "20/20 hindsight", it is evident that this problem might have been avoided or at least minimized, by the use of better installation instructions and procedures not available at the time of initial system installation.

Based on the analysis of test results conducted by Ft Belvoir Research Engineering and Development Center, EG & G Consultants, and Computing Devices, the following recommendations are offered:

a) Ensure that the next phase of the program includes appropriate effort and tasking to properly define, test, and recommend a Standard Site Selection Criteria, and General Installation Procedures

b) Ensure that the next phase of the program includes a task to evaluate and test electronic techniques to further reduce installation restrictions, identified by this series of tests, while maintaining the current high Pd performance.

c) Include as part of the next program phase, a cooperatively based, User/Developer series of test requirements, where various types of Facilities and resources may be defined to be typical of resources to be protected, and tested accordingly.

A BACKGROUND SUMMARY

Prior to commencement of testing at Eglin Air Force Base, the PINTS systems had been under test, both at the Computing Devices Test Facility, and at Ft. Belvoir. Testing included EDT, DT-1 and DT-1A, with all of the test results during those tests indicating sensor performance well above original design requirements.

During all of these tests, the false alarm rate was considered to be well below specified requirements will the detection performance, especial at slow speed, was an order of magnitude better than the specified requirements.

It is also significant that the "Installation Knowledge Envelope" for this new type of Sensor was primarily gained from the installation of the two storage facilities at Ft. Belvoir, with restricted tested done in other facilities.

Confined by a small installation knowledge experience base, and the fact that installation procedures and detailed site selection guidelines had not yet been refined, both the choice of test site, and the installation procedures used, could now be considered to be significant contributing factors to the poor test results initially obtained.

Clearly, the higher than expected false alarm rate experienced at the Eglin Test site was not typical of the performance shown by the Sensor during any aspect of the previous tests, and deserved an appropriate investigation.

In summary, the following pages briefly outline:

- A summary of the factors initially believed to be possible sources of the high FAR rate.

- Results of the investigation to reduce and determine the FAR source.

- A brief conclusion based on the results of the test results analysis.

[illegible] SOURCES OF SUSPECTED FAR [illegible]

Immediately following formal testing at Eglin AFB, and based on reports of higher than expected FAR rate, the investigation team of AFEDC, EG & G, and Computing Devices, identified then individually tested the following list of possible FAR sources.

1. Improperly adjusted, or malfunctioning sensor hardware.

2. Sensor internal or self generated FAR alarms.

3. FAR alarms caused by and external EMI sources.

4. Local traffic or phenomena near the sensor, but outside the detection zone.

5. Events occurring within the detection zone.

6. Problems caused by installation techniques and/or procedures

RESULTS OF INITIAL TEST INVESTIGATIONS

Each of the suspected sources of high FAR were individually isolated and evaluated as follows.

1. Sensor Hardware Integrity

Upon arrival at the Eglin test facility, and without any hardware, or installation changes, an "as installed" investigation of the sensor hardware was performed. Upon investigation, it was found that although one cable connector was of questionable integrity and a stimulus unit did not seem to be functioning as expected, the sensor hardware was found to be functioning normally, and with the threshold and detection parameters still set where they were initially left, prior to start of CET testing.

Neither the connector problem nor the stimulus problem could have significantly contributed to the high FAR, and were repaired such that testing could continue.

2. Internally / Self Generated FAR alarms

A series of tests which eliminated all probabilities of externally generated FAR alarms were done. The results of these tests indicated that the FAR source was not internal to the electronics unit, and must therefore be external to the FINTS electronics unit. These tests included using a battery to eliminate power input sources, termination of all receiver and transmitter ports to preclude external EMI/RF sources, and various FIDS and FIDSIM tests to eliminate sources caused from control/link interfaces.

The results of these tests clearly indicated that the FAR source was not internally or control link generated.

3. External Electromagnetic Interference (EMI) Sources.

With the use of broadband EMI source monitoring equipment, over the period of several days, an attempt to correlate FAR alarms to specific spectral activity was attempted. Although during this test period, a significant number of FARs were logged, no conclusive correlation to external EMI events could be made.

Although not specifically conclusive, the lack of a clear correlation of events was judged to be an indication that EMI sourced FAR's were very unlikely.

4. Local traffic or phenomena near Facility, but outside detection zone.

Once again, with the sensor performing in the same fashion as during the CET tests, external events such as vehicular traffic, local aircraft taxiing near by, and physically moving various building structures were done and an attempt to correlate these activities with FAR alarms.

In most cases, little to no correlation or repeatable occurrences of events was obtained. In several cases, however, actions such as opening and closing certain wooden doors within the building seemed to correlate loosely with the FAR alarms, as did the starting of a water cooler well outside of the apparent detection zone.

5. Events occurring within the detection zone

Of particular interest, in both of the rooms under test, a suspended ceiling structure was located well inside of established detection zones. A series of test involving both the moving of the cables to preclude the ceiling from the zone and a series of phenomenology confirmations tests were done that confirmed a significant source of FAR alarms could be attributed to having the suspended ceiling within the detection zone.

It was also noted that the closing of doors mentioned in item 5 the effected of causing a room to r deferential, that in turn caused th ceiling to noticeable move.

A series of tests were then dor performance with different cable/zone scenarios that added confidence to the that a significant FAR source identified. (Suspended ceiling)

6. Installation Techniques and Procedures

In addition to the FAR sources above, it was also noted that perfor smallest of rooms was likely being a field coupling mechanisms that effe the Lead-in cables "Hot", and detection zone, and thereby allowin sources. (Water cooler) Use of Ferri "Deaden" the hot lead-ins were of som the most practical solution for e sensor performance is simply to d installation techniques to eliminate problems.

Also noted were Pd variations in were the transmitter and receiver significantly different lengths. installation guidelines would this variation.

TEST ANALYSIS CONCLUSIONS

The results of the test analysis at Eglin AFB, are indeed positive and encouraging. Although unexpected at the onset of the CET tests, these tests have contributed to a better understanding of necessity of better installation and site selection guidelines, and the need to continue to deploy and improve the installation knowledge data base, such that production systems will benefit from the collection of this experience base.

All of the problems identified are generally solvable with either better installation procedures and/or sensor performance enhancements that reduce installation restrictions.

DISTRIBUTION FOR REPORT NO. 2465

DEPARTMENT OF DEFENSE

1 Director, Technical Information
Defense Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

1 Director
Defense Nuclear Agency
ATTN: TITL
Washington, DC 20305

2 Defense Technical Information Center
Cameron Station
ATTN: DTIC-FDAC
Alexandria, VA 22304-6145

DEPARTMENT OF THE ARMY

1 HQDA (DAMA-AOA-M)
Washington, DC 20310

1 HQDA (DALO-TSM)
Washington, DC 20310

1 HQDA (DAEN-RDL)
Washington, DC 20314

1 HQDA (DAEN-MPE-T)
Washington, DC 20314

1 Commander
US Army Missile Research & Development Command
ATTN: AMSMI-PR
Redstone Arsenal, AL 35809

1 Director
Army Materials and Mechanics Research Center
ATTN: AMXMR-RL Technical Library
Watertown, MA 02172-0001

1 Commander
Chemical Research R&D Center
ATTN: SMCCR-SPS (Tech Library)
Aberdeen Proving Ground, MD 21005

1 Commander
US Army Aberdeen Proving Ground
ATTN: STEAP-MT-U (GE Branch)
Aberdeen Proving Ground, MD 21005

1 Director
US Army Materiel Systems Analysis Agency
ATTN: AMXSY-MP
Aberdeen Proving Ground, MD 21005-5071

1 Director
US Ballistics Research Laboratory
ATTN: AMXBR-OD-ST (STINFO)
Aberdeen Proving Ground, MD 21005-5066

1 Director
US Army Engineer Waterways Experiment Station
ATTN: Chief, Library Branch
Technical Information Center
Vicksburg, MS 39180

1 Commander
US Army Armament Research & Development Command
ATTN: SMCAR-TSS
Dover, NJ 07801-5001

1 Commander
US Army Troop Support & Aviation Materiel Readiness Command
ATTN: DRSTS-MES (1)
4300 Goodfellow Blvd.
St. Louis, MO 63120

2 Director
Petrol & Fld Svc Dept
US Army Quartermaster School
Fort Lee, VA 23801

1 US Army Tank Automotive Command
ATTN: DRSTA-TSL
Warren, MI 48090

1 US Army Laboratory Command
ATTN: M. Levy SLCMT-MN
Materials Technology Laboratory
Watertown, MA 02172-0001

1 US Army Laboratory Command
ATTN: J. Wells SLCMT-MCZ
Materials Technology Laboratory
Watertown, MA 02172-0001

1 Commander
US Army Electronics Research &
Development Command
ATTN: DELSD-L
Fort Monmouth, NJ 07703-5301

1 President
US Army Aviation Test Board
ATTN: STEBG-PO
Fort Rucker, AL 36360

1 US Army Aviation School Library
PO Drawer O
Fort Rucker, AL 36360

1 HQ 193D Infantry Brigade (Panama)
ATTN: AFZU-FE
APO Miami 34004

2 Special Forces Detachment, Europe
ATTN: PBO
APO New York 09050

2 Engineer Representative
USA Research & Standardization Group
(Europe)
Box 65
FPO 09510

1 Commander
Rock Island Arsenal
ATTN: SARRI-LPL
Rock Island, IL 61299-7300

1 HQDA
ODCSLOG
DALO-TSE
Room 1E588, Pentagon
Washington, DC 20310-0561

1 Plastics Technical Evaluation Center
ARRADCOM, Bldg 3401
Dover, NJ 07801

1 Commandant
US Army Engineer School
ATZA-CDD
Fort Belvoir, VA 22060

1 US Army AMCCOM
ATTN: Joseph Menke
1032 N. Thornwood
Davenport, IA 52804

1 Commander
Headquarters, 39th Engineer Bn (Cbt)
Fort Devens, MA 01433

1 President
US Army Airborne, Communications &
Electronics
ATTN: STEBF-ABTD
Fort Bragg, NC 28307

1 President
US Army Armor and Engineer Board
ATTN: ATZK-AE-PD-E
Fort Knox, KY 40121-5470

1 Director
ATTN: STSTO-TPP
Tobyhanna Army Depot
Tobyhanna, PA 18466-5097

1 Commander and Director
USA FESA
ATTN: FESA-TS
Fort Belvoir, VA 22060

1 HQ, USAEUR & Seventh Army
Deputy Chief of Staff, Engineer
ATTN: AEAEN-MT-P
APO New York 09403

1 Director
US Army TRADOC
Systems Analysis Activity
ATTN: ATAA-SL (Tech Lib)
White Sands Missile Range, NM 88002

BELVOIR RD&E CENTER

Circulate

1 Commander STRBE-Z
Deputy Commander STRBE-ZD
Technical Director STRBE-ZT
Assoc Tech Dir (E&A) STRBE-ZTE
Assoc Tech Dir (R&D) STRBE-ZTR
Executive Officer STRBE-ZX
Sergeant Major STRBE-ZM
Advanced Systems Concept Dir STRBE-H
Program Planning Div STRBE-HP
Foreign Intelligence Div STRBE-HF
Systems and Concepts Div STRBE-HC
STRBE-J

100 STRBE-JIC
3 Tech Reports Ofc STRBE-BPG
3 Security Ofc (for liaison officers) STRBE-S
2 Tech Lib STRBE-BT
1 Public Affairs Ofc STRBE-I
1 Ofc of Chief Counsel STRBE-L

DEPARTMENT OF THE NAVY

1 Director
Physics Program (421)
Office of Naval Research
Arlington, VA 22217

2 Commander
Naval Facilities Engineering Command
Department of the Navy
ATTN: Code 032-B
062
200 Stovall Street
Alexandria, VA 22332

1 US Naval Oceanographic Office
Navy Library/NSTL Station
Bay St. Louis, MO 39522

1 Library (Code L08A)
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, CA 93043

1 Director
Earth Physics Program
Code 464
Office of Naval Research
Arlington, VA 22217

1 Naval Training Equipment Center
ATTN: Technical Library
Orlando, FL 32813

3 Naval Sea Systems Command
ATTN: P. Schneider PMS377J1
Wasington, DC 20362-5101

1 Naval Air Development Center
ATTN: V. S. Agarwala, Code 6062
Warminster, PA 18974

3 David W. Taylor Naval Research Center
ATTN: A. G. S. Morton
Code 2813
Annapolis, MD 21402

DEPARTMENT OF THE AIR FORCE

1 HQ USAF/RDPT
ATTN: Commander
Washington, DC 20330

1 HQ USAF/PREEU
Chief, Utilities Branch
Washington, DC 20330

1 HQ Air Force Engineering & Services Ctr
Technical Library FL7050
Tyndall AFB, FL 32403

1 US Air Force
Warner Robins Air Logistics Center
WR-ALC/MMEM
Warner-Robins AFB, GA 31098

1 Chief, Lubrications Branch
Fuels & Lubrications Div
ATTN: AFWAL/POSL
Wright-Patterson AFB, OH 45433